Review of Literature Related to Exotic Snail & Slug Invasiveness in Wisconsin, a report to the Wisconsin Council on Invasive Species, Species Assessment Group

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Current status

Roy (1963) published a checklist with citations for all mollusk species that had been reported from Wisconsin, both native and exotic. In a literature review funded by the Wisconsin Department of Agriculture, Trade & Consumer Protection, Jass (2004) presented Wisconsin county-level records for 80 terrestrial gastropods, 10% of these being introduced European species.

A necessary background for assessing the impact of exotic slugs and land snails on forests and other natural habitats is knowledge of the native fauna. Hubricht (1985) identified Wisconsin as one of the Eastern states most in need of survey work on its native land mollusks. Subsequent to his summary of distribution records, Hubricht provided determinations for all Wisconsin terrestrial gastropods in the Milwaukee Public Museum (MPM) collection (Jass 1986), including those from meter by meter leaf litter samples from a dozen sites in natural habitats across the southern half of the state, which averaged 84 specimens/square meter (Jass et al. 1999). Several excellent publications by professional malacologists in the state have resulted from recent research focused especially on scientific analysis of particular habitat or soil types. James Theler of the University of Wisconsin (UW)-La Crosse reported (1997) on his multi-year study of the land snail fauna of western Wisconsin's hill prairies. Jeffrey Nekola, then with UW-Green Bay, focused (1999, 2003, 2004, Nekola & Smith 1999, and Nekola et al. 1996) on gastropods from carbonate cliffs and associated habitats in the Great Lakes basin.

Though the State of Wisconsin has listed several terrestrial snails as threatened or endangered (Wisconsin Department of Natural Resources 1999 and online), there have been few comprehensive statewide surveys for gastropods in the state's natural ecosystems. As part of several survey trips made in 1949, UW zoologists collected 46 land snail species at 61 sites in 43 counties, mostly in habitats they described (Levi & Levi 1950) as deep woods. The Levi collecting records may be used as a baseline for comparison with current efforts. For example, at Point Beach State Forest where the Levis had found 5 native species, MPM collectors in 2006 searched for an hour, using methods assumed to be similar to those of the Levis, and found no snails but instead many specimens of the invasive slug *Arion subfuscus*.

In 2004 the United States Department of Agriculture (USDA), charged with monitoring invasives as potential crop pests, held a regional workshop at MPM entitled Milwaukee Slugfest, as part of the North American Slug Project (NASP). The aim of NASP is to alleviate the "greatest difficulty in making and carrying out policy regarding slugs ... that we lack sufficient data on the species currently living in North America and their geographic distributions" (Robinson 2004). The NASP federal survey program has the goal of defining anatomically and through DNA analysis all slug species, both native and introduced. NASP emphasizes that in many cases, a gastropod's external morphology does not allow one to make an accurate identification to species. Instead one needs to rely on dissection of an adult or near adult--most

individuals encountered are immatures (Robinson 2004)--for an internal view of penis shape and appendages. For some slugs however, the male genitalia can be lost during development.

Both the understanding of the ecological dynamics of terrestrial gastropods in natural habitats and the taxonomy of these species are in large part still in the basic research phase of science. Regarding taxonomy, standard references such as the volumes of Pilsbry's (1948) monograph have been supplemented recently by regional aids available online (for example, see Minnesota Department of Natural Resources, Land Snail Reports, various dates). Some formerly accepted terrestrial gastropod species are currently undergoing review and may turn out to be species complexes that include more than one taxonomically valid entity (see for example Pearce & Bayne 2003).

The following 13 species are the nonindigenous gastropods in Wisconsin, as named by Turgeon et al. (1998). [A new edition of this reference is due in 2008, but the USDA updates its listings of targeted pests more frequently online http://www.invasive.org/listview.cfm?list=3.] County records are arranged first in chronological order; those dated from a single reference from the Literature Cited are listed alphabetically by county name. Those with the initials MPM are from the Milwaukee Public Museum collection.

#1 *Arion fasciatus*, Arionidae, orange-banded arion [slug]
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1948 (Pilsbry) Dane; 1968 (Getz) Oneida, Vilas; 1978 (MPM) Milwaukee; 1980 (MPM) Washington; 2004 (Jass) Fond du Lac, Green, Racine, Sheboygan, Waukesha, Winnebago; 2006 (MPM) Manitowoc; 2007 (MPM) Taylor.

#2 *Arion hortensis*, Arionidae, garden arion [slug]
Note: This is a complex of 3 non-native species -- *A. distinctus*, *A. hortensis*, *A. owenii* -- best told apart by dissection (Pearce & Bayne 2003).
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 2004 (Nekola) not mapped; 2006 (MPM) Ozaukee; 2007 (MPM) Sheboygan.
Quarantine status: already established in the United States, not actionable (Robinson 2004).

#3 *Arion rufus*, Arionidae, chocolate arion [slug]
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 2003 (MPM) Sheboygan; 2005 (DATCP/MPM) Dane, Milwaukee; 2006 (MPM) Eau Claire.
Quarantine status: already established in the United States, not actionable (Robinson 2004)

#4 *Arion subfuscus*, Arionidae, dusky arion [slug]
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1962 (MPM) Milwaukee; 2006 (MPM) Douglas, Manitowoc; 2007 (MPM) Iron.
Quarantine status: already established in the United States, although Kerney (1999) has suggested that it may also be native to North America; not actionable (Robinson 2004), but in 2006 listed online as a USDA Eastern Region pest species.

#5 *Cornu* [formerly *Helix*] *aspersum*, Helicidae, brown gardensnail
Original range: Mediterranean and W. European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 2006 (DATCP/MPM) St. Croix.

#6 *Deroceras laeve*, Limacidae, meadow slug [synonym: *Agriolimax campestris*]
Original range: Holarctic, but probably both indigenous and nonindigenous populations occur in North America (T.A. Pearce pers. comm. 2003).

Reported in Wisconsin counties: 1905 (Chadwick) Milwaukee; 1986 (Jass) Crawford, Ozaukee; 1997 (Theler) Pepin, Vernon; 2004 (Jass) Fond du Lac, Kenosha, Racine, Rock, Sheboygan, Winnebago; 2006 (MPM) Columbia; 2007 (MPM) Buffalo, Calumet, Langlade, Marathon, Oneida.
Quarantine status: established worldwide, not actionable (Robinson 2004).
#7 *Deroceras reticulatum*, Limacidae, gray fieldslug
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1900 (MPM) Milwaukee; 1948 (Pilsbry) Dane; 1962 (MPM) Kenosha; 1978 (MPM) Ozaukee; 1980 (MPM) Washington; 2004 (Jass) Columbia, Waushara; 2006 (MPM) Barron, Green, Manitowoc, Rock; 2007 (MPM) Clark.
Quarantine status: established worldwide, not actionable (Robinson 2004).
#8 *Helix pomatia*, Helicidae, escargot
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1905 (Chadwick) Milwaukee; 1941 (Washburn) Waukesha.
#9 *Limax flavus*, Limacidae, yellow gardenslug or yellow cellar slug
Original range: Mediterranean (Kerney 1999)
Reported in Wisconsin counties: 1905 (Chadwick) Milwaukee.
Quarantine status: established in the United States, not actionable (Robinson 2004).
#10 *Limax maximus*, Limacidae, giant gardenslug or leopard slug
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1911 (MPM) Milwaukee.
Quarantine status: established throughout the United States, not actionable (Robinson 2004).
#11 *Oxychilus cellarius*, Zonitidae, cellar glass-snail
Original range: European (Kerney & Cameron 1979).
Reported in Wisconsin counties: 1905 (Chadwick) Milwaukee, Waukesha; 2004 (Nekola) Door; 2006 (MPM) Barron.
#12 *Oxychilus draparnaudi*, Zonitidae, dark-bodied glass-snail
Original range: Mediterranean (Kerney 1999).
Reported in Wisconsin counties: 1980 (MPM) Milwaukee; 2004 (Nekola) Door.
#13 *Polygyra*, probably *cereolus*, Polygyridae, southern flatcoil
Original range: Florida and adjacent states (Hubricht 1985).
Reported in Wisconsin counties: 2006 (MPM) Eau Claire.

Introduction potential

As a group, mollusks do have a documented history (Dundee 1974) with regard to introductions of invasive species into North America. Within the last decade however, attention to the potential impact of such introductions has become intensified. According to the American Malacological Society's Council of Systematic Malacologists (Turgeon et al. 1998): "Introduction of invasive nonindigenous species is currently one of the most critical issues in natural resource management and conservation. Invasive species are known to alter population, community, and ecosystem structure and function. Changes in ecosystems that alter water, nutrient, and energy cycles, as well as productivity and biomass, directly affect human society."

Cowie & Robinson (2003) gave a detailed summary of the known or presumed introduction pathways, both deliberate and inadvertent, for nonindigenous land snails and slugs. Slugs and terrestrial snails are most often introduced by accident, being easily transported on various materials without the knowledge of those handling the material. In the unusual case of

someone harboring a non-native species on purpose (ex. raising escargot for food), the owner's economic interest may to some degree provide incentive to guard against the escape of captives. Occasionally, the use of snails for educational displays or as pets has brought invasive species to Wisconsin (USDA 2004).

The history of terrestrial gastropod introductions to Wisconsin is a long one (Chadwick 1905, 1906). Using the two largest introduced terrestrial gastropods that have become established in Wisconsin over the last century -- the escargot snail *Helix pomatia* with a shell diameter up to 4.5 cm [1.8 inches] and weight to 8 grams and the giant gardenslug *Limax maximus* with an extended length when alive up to 20 cm [7.8 inches] -- it is worth noting that both have been deemed non-actionable by the USDA (Lambrecht 2004, Robinson 2004).

Damage potential

Most of the available evidence regarding damage caused by exotic snails and slugs pertains to agricultural rather than forest or other natural situations. Abbott (1950) presented a readable summary of the potential negative effects of what he termed a 'Fifth Column' of introduced gastropods already entrenched on our continent -- in some cases capable of carrying parasitic diseases, and he called for scientists, farmers and quarantine officials to take the matter seriously. He mentioned the expense, both public and private, that had been incurred by attempts to eradicate exotic land snails, and speculated that it would be difficult to control their dispersal by even the best of legal means because of increasing transport of shipments of agricultural products from abroad. Instances supporting such early predictions regarding the potential for damage to crops -- from lettuce to citrus foliage -- have been well documented since, though most have come from a few high profile agricultural pest species in states like California and Florida whose climates lack a Wisconsin winter, thus giving introductions there an extra chance to survive and thrive.

Although distributions of invasive species show significant correlation with habitats most disturbed by human activity (earning them the name "synanthropes"), at least some of these species have the potential to expand their ranges, spreading out into the countryside. Grimm (1996) found certain European slug species to have become thoroughly naturalized in relatively undisturbed forests in Canada, and also noted that these were fairly omnivorous, while the native slugs were as a rule mycophagous. Such differences in diet may well be key to the destructiveness potential of the invasives. In an experimental study, Frank (2003) noted that certain wildflower species were drastically reduced by European slug herbivory.

Research is still underway to identify those behavioral and/or genetic factors that enable an exotic species to rapidly increase in numbers and become a pest. A molecular component just now being discovered in some slugs in Europe (the source of many of the gastropods intercepted coming into the United States) is a genetic propensity -- shown sometimes only by certain variants within a single species -- to exhibit traits of behavior and population dynamics which give those with the traits a special ability to rapidly colonize new territory (Pinceel et al. 2004, 2005).

Pioneering research into the effects of invasive invertebrates, earthworms in particular, on northern hardwood forests has been conducted by the University of Minnesota Department of Forest Resources (Tiunov et al. 2006, Holdsworth et al. 2007). Some evidence from this work has suggested that the dynamics involved include interrelationships not only with plant species diversity, soil conditions and deer abundance but also with the prevalence of invasive slugs, specifically the dusky arion *Arion subfuscus*, whose density was correlated with seedling

mortality rates of certain plant species (Holdsworth pers.comm. 2005). Deer overabundance especially has been the focus of recent discussion in the literature (Martin 2006, Örstan 2006, Suominen 2006) regarding its potential negative impact on terrestrial mollusks. Hotopp & Pearce (2007) discuss some initial findings that forests whose soils have changed to become increasingly acid may lose native snails and see an increase in slug densities, because of the acid's negative effect on calcium needed for the formation of shells.

In Wisconsin a 2003-4 survey funded by the Lois Almon Small Grants Program (Jass 2004a, Jass & Klausmeier 2005) attempted to document this invasion process as it might be occurring in the leaf litter layer of State Natural Areas in 21 counties in the southeastern corner of the state. With beaten paths and the abundance of plants such as buckthorn and poison ivy as a rough indication of the amount of human traffic, observations seemed to provide some support for the generalization that the heavier the use of the habitat, the more invasive invertebrates appeared in the leaf litter samples.

Prevention and control potential

For terrestrial snails and slugs, simply prohibiting the intentional introduction of non-native species is probably especially ineffective in addressing potential threats to the state's ecosystems from these species because, more than most other introductions, they or their eggs (Hanna 1969) are so often transported totally hidden from view, as in soil or plant debris.

The use of poisoning for control may have the double hazard of not fully eradicating the pest, while at the same time adversely affecting native gastropods as well as other organisms (Ferguson 2004). Kleinkauf et al. (1999) found that the most commonly used slug pellet poisons, methaldehyde and methiocarb, caused bird and small mammal mortalities and so recommended a safer alternative. Bowen & Ali (2005) reported the development of new non-toxic repellents for terrestrial mollusks. The 2004 regional NASP workshop included a fieldtrip to the Schiller Park Canadian Pacific railroad yards in Cook County, Illinois, where an exotic snail (*Monacha cartusiana*) infestation had been found previously and treated with poison baits. Searching in that previously baited area yielded no gastropods, exotic or native. But at a site nearby in the same railroad yard, a new infestation of the exotic snail was discovered.

Perhaps an appropriate category for regulation of terrestrial gastropod introductions to Wisconsin is the informal one of Watch. Systematic monitoring may well be the best possible method of detecting and addressing potential problems to the State from introduced slugs and terrestrial snails. As the federally funded NASP goals stated (Robinson 2004), assignment to any other regulation category would be premature at this time.

Literature cited

Abbott, R.T. 1950. Snail invaders. Natural History, 59 (2): 80-85.

Bowen, I.D. and A. Ali. 2005. Non-toxic slug repellents and antifeedant sprays. Tentacle, 13: 7.

Chadwick, G.H. 1905. List of Wisconsin shells. The Nautilus, 19(5):57-60, 20(2):22-24.

Chadwick, G.H. 1906. Notes on Wisconsin Mollusca. Bulletin of the Wisconsin Natural History Society, 4(3):67-99.

Cowie, R.H. and D.G. Robinson. 2003. Pathways of introduction of nonindigenous land and freshwater snails and slugs. In: Invasive species: vectors and management strategies (eds. Ruiz, G. & Carlton, J.T.) p. 93-122. Island Press, Washington, D.C. http://www.cdfa.ca.gov/phpps/ppd/Entomology/Snails/pathwayspub.htm

Dundee, D.S. 1974. Catalog of introduced molluscs of eastern North America. Sterkiana 55: 3-37.
Ferguson, S.H. 2004. Effects of poisoning nonindigenous slugs in a boreal forest. Canadian Journal of Forest Research, 34: 449-455.
Frank, T. 2003. Influence of slug herbivory on the vegetation development in an experimental wildflower strip. Basic and Applied Ecology, 4 (2): 139-147.
Getz, L.L. 1968. *Arion fasciatus* in Wisconsin. The Nautilus 82(1): 32-33.
Grimm. F.W. 1996. Terrestrial molluscs. In: Assessment of species diversity in the mixedwood plains ecozone (Smith, I.M. ed.), Ecological Monitoring and Assessment Network, Agriculture Canada, Naturewatch. www.naturewatch.ca/MixedWood/
Hanna, M. 1969. Dispersal of *Helix aspersa* with container grown nursery stock. The Nautilus, 82(4): 145.
Holdsworth, A.E., Frelich, L.E., and P.B. Reich. 2007. Effects of earthworm invasion on plant species richness in northern hardwood forests. Conservation Biology, 21(4): 997-1008.
Hotopp, K.P. and T.A. Pearce. 2007. Land Snails of Pennsylvania. Carnegie Museum of Natural History, Pittsburgh, PA, USA. http://www.carnegiemnh.org/mollusks/palandsnails/
Hubricht, L. 1985. The distributions of the native land mollusks of the eastern United States. Fieldiana, Zoology, New Series, No.24:1-191.
Jass, J.P. 1986. Supplemental distribution records for Wisconsin terrestrial gastropods. Transactions of the Wisconsin Academy of Sciences, Arts and Letters, 74: 105-107.
Jass, J.P. 2004. Distributions of gastropods in Wisconsin. Milwaukee Public Museum Contributions in Biology and Geology, N.99:1-28.
Jass, J.P. 2004a. Assessment of southeastern Wisconsin State Natural Areas for presence of nonindigenous species of terrestrial isopods, slugs and earthworms. Final Report, Lois Almon Small Grants Program for 2003, Wisconsin Academy of Sciences, Arts, and Letters.
Jass, J., Glenn, J. and M. Suffoletta. 1999. A wealth of biodiversity: terrestrial gastropods. Wisconsin Academy of Sciences, Arts and Letters, 29th Annual Conference, Abstracts of Papers & Posters, 17.
Jass, J. and B. Klausmeier. 2005. Invasive slug (*Arion fasciatus*) in Cedarburg Beech Woods. University of Wisconsin-Milwaukee Field Station Annual Report, 2004: 14.
Kerney, M.P. 1999. Atlas of the Land and Freshwater Molluscs of Britain and Ireland. Harley, Colchester, England, 264 pp.
Kerney, M.P. and R.A.D. Cameron. 1979. A Field Guide to the Land Snails of Britain and North-west Europe. Collins, London, 288 pp.
Kleinkauf, A., MacDonald, D.W. and F.H. Tattersall. 1999. A bitter attempt to prevent non-target poisoning of small mammals. Mammalogical Review, 29(3): 201-204.
Lambrecht, K. 2004. Alerts: *Helix pomatia* (French escargot). Wisconsin Pest Bulletin, 49(13): 2.
Levi, L.R. and H.W. Levi. 1950. New records of land snails from Wisconsin. The Nautilus, 63(4):131-138.
Martin, J-L. 2006. Could deer overabundance impact terrestrial mollusks?--a response to Örstan. Tentacle, 14: 21-22.

Minnesota Department of Natural Resources, Division of Ecological Services. Land Snail Reports. Detailed reports by several authors, including one with SEM photos and identification keys for Wisconsin by Matt Barthel and Jeff Nekola. http://www.dnr.state.mn.us/eco/nongame/projects/research_reports/snails.html

Nekola, J.C. 1999. Terrestrial gastropod richness of carbonate cliff and associated habitats in the Great Lakes region of North America. Malacologia, 41(1): 231-252.

Nekola, J.C. 2003. Large-scale terrestrial gastropod community composition patterns in the Great Lakes region of North America. Diversity and Distributions, 9: 55-71.

Nekola, J.C. 2004. Terrestrial gastropod fauna of Northeastern Wisconsin and the Southern Upper Peninsula of Michigan. American Malacological Bulletin, 18 (1 / 2) :21-44.

Nekola, J.C. and T.A. Smith. 1999. Terrestrial gastropod richness patterns in Wisconsin carbonate cliff communities. Malacologia, 41(1): 253-269.

Nekola, J.C., Smith, T.A. and T.J. Frest. 1996. Land snails of Door Peninsula natural habitats. Final Report, Wisconsin Chapter, The Nature Conservancy. 65 pp. + maps.

Örstan, A. 2006. Could deer overabundance impact terrestrial mollusks? Tentacle, 14: 20-21.

Pearce, T.A. and E.G. Bayne. 2003. *Arion hortensis* Ferussac, 1819, species complex in Delaware and Pennsylvania, Eastern USA (Gastropoda: Arionidae). The Veliger, 46(4): 362-363.

Pilsbry, H.A. 1948. Land Mollusca of North America (North of Mexico). Monograph of the Academy of Natural Sciences, Philadelphia 2(2): 521-1113.

Pinceel, J., Jordaens, K., Van Houtte, N., De Winter, A.J. and T. Backeljau. 2004. Molecular and morphological data reveal cryptic taxonomic diversity in the terrestrial slug complex *Arion subfuscus/fuscus* (Mollusca, Pulmonata, Arionidae) in continental north-west Europe. Biological Journal of the Linnean Society 83: 23-38.

Pinceel, J., Jordaens, K., Pfenninger, M. and T. Backeljau. 2005. Rangewide phylogeography of a terrestrial slug in Europe: evidence for Alpine refugia and rapid colonization after the Pleistocene glaciations. Molecular Ecology 14: 1133-1150.

Robinson, D.G. 2004. United States Department of Agriculture, North American Slug Project printouts distributed at Milwaukee Slugfest 2004, Milwaukee Public Museum.

Roy, E.C., Jr. 1963. Checklist of Pleistocene and living Mollusca of Wisconsin. Sterkiana, 10:5-21.

Suominen, O. 2006. Cervids and gastropods--a response to Örstan. Tentacle, 14: 22.

Theler, J.L. 1997. The modern terrestrial gastropod (land snail) fauna of western Wisconsin's hill prairies. The Nautilus 110(4): 111-121.

Tiunov, A.V., Hale, C.M., Holdsworth, A.R., and T.S. Vsevolodova-Perel. 2006. Invasion patterns of Lumbricidae into the previously earthworm-free areas of northeastern Europe and the western Great Lakes region of North America. Biological Invasions, 8(6): 1223-1234.

Turgeon, D.D., Quinn, J.F. Jr., Bogan, A.E., Coan, E.F., Hochberg, F.G., Lyons, W.G., Mikkelsen, P.M., Neves, R.J., Roper, C.F.E., Rosenberg, G., Roth, B., Scheltema, A., Thompson, F.G., Vecchione, M. and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd ed. American Fisheries Society, Bethesda, Maryland. 526 pp.

United States Department of Agriculture, Animal and Plant Health Inspection Service. 2004. Safeguarding, Intervention, and Trade Compliance officers confiscate giant African snails in Wisconsin. Pest Alert, APHIS 81-35-008, January.

Washburn, R.G. 1941. A Wisconsin colony of *Helix pomatia*. The Nautilus, 54(4): 145.
Wisconsin Department of Natural Resources, Bureau of Endangered Resources. 1999. The endangered and threatened invertebrates of Wisconsin. Madison. 80 pp. http://www.dnr.state.wi.us/org/land/er/invertebrates/snails/index.htm